

# NAVAL RESEARCH LABORATORY

## NAVAL CENTER FOR SPACE TECHNOLOGY

GLAST LAT Calorimeter Subsystem  
Electromagnetic Interference Test Report  
Qualification Testing

**GLAST LAT Doc Number: LAT-TD-05203-01**

**NCST-TR-#####**

**09 November 2004**



4555 Overlook Avenue, S.W.  
Washington, D.C. 20375-5000

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Washington, D.C. 20375-5000**

NCST-TR-#####

RECORD OF CHANGES

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NCST-TR-#####

RECORD OF CHANGES

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## NCST-TR-#####

## TABLE OF CONTENTS

Section	Title	Page
1	General.....	7
1.1	Introduction.....	7
1.2	Test Summary.....	7
1.3	Applicable Documents.....	7
1.3.1	Military.....	7
1.3.2	NRL.....	8
2	Unit Under Test (UUT).....	8
2.1	UUT Description.....	8
2.2	UUT Electromagnetic Compatibility Requirements.....	8
2.3	UUT Configuration.....	8
2.3.1	Modes of Operation.....	8
2.3.2	Connector and Cable Configuration.....	8
2.3.3	Power Requirements.....	8
3	EMI Test Facilities.....	8
3.1	Test Data.....	8
3.2	Test Enclosure.....	9
3.3	Ground Plane.....	9
3.4	Test Equipment.....	9
4	Test Procedures.....	9
4.1	Test Procedure Issues.....	9
5	Test Results.....	9
5.1	EMI Test Preliminary Set-Up.....	9
5.2	Pre-EMI Functional Test of Flight CAL.....	9
5.3	Conducted Emissions, Power Leads, 10kHz - 10MHz (CE102).....	9
5.4	Conducted Emissions, Time Domain, 150MHz Bandwidth (CECM).....	10
5.4.1	Conducted Emissions, Common Mode (CECM).....	10
5.4.2	Conducted Emissions, Differential Mode (CEDM).....	10
5.5	Conducted Susceptibility, Power Leads, 10kHz - 10MHz (CS102).....	10
5.6	Conducted Susceptibility, Common Mode, 30Hz - 150MHz (CSCM).....	10
5.7	Conducted Susceptibility, Power Leads, Spikes (CS06).....	11
5.8	Radiated Emissions, Magnetic Field, 20Hz - 50kHz (RE101).....	11
5.9	Radiated Emissions, Electric Field, 10kHz - 18GHz (RE102).....	11
5.10	Radiated Susceptibility, Magnetic Field, 20Hz - 50kHz (RS101).....	12
5.11	Radiated Susceptibility, Electric Field, 30MHz - 18GHz (RS103).....	12
5.12	Static Magnetic Field.....	12
5.13	Post EMI/EMC Performance Test.....	12

NCST-TR-#####

TABLE OF CONTENTS

Section	Title	Page
Appendix A	- CE102 Test Data (Plot_001 to Plot_003).....	A-1
Appendix B	- CECM Test Data (Plot_004 to Plot_018).....	B-1
Appendix C	- CS102 & CSCM Test Data (Plot_022 to Plot_051).....	C-1
Appendix D	- CS06 Test Data (Plot_019 to Plot_021).....	D-1
Appendix E	- RE101 Test Data (Plot_084 to Plot_096).....	E-1
Appendix F	- RE102 Test Data (Plot_052 to Plot_083, and Plot_097 to Plot_104).....	F-1
Appendix G	- RS101 Test Data (Plot_117 to Plot_163).....	G-1
Appendix H	- RS103 Test Data (Plot_105 to Plot_116).....	H-1
Appendix I	- Log Book Entries.....	I-1
Appendix J	- Photographs.....	J-1

**LIST OF FIGURES AND TABLES**

<b>Number</b>	<b>Title</b>	<b>Page</b>
Table 1-1.	Test Requirements and Results Summary.....	7

## NCST-TR-#####

## 1 GENERAL

**1.1 Introduction.** This document contains the details which characterizes the electromagnetic emissions characteristics of the GLAST LAT Calorimeter Subsystem. Qualification testing was conducted in accordance with the "Electromagnetic Interference (EMI) Test Procedure" LAT-PS-03929-03 (07 Sep 2004), at the Naval Research Laboratory. Setup of the EMI test facilities, Support Test Equipment (STE), setup of the CAL began on 13 September 2004, and testing ended on 20 September 2004.

**1.2 Test Summary.** Table 1-1 summarizes the qualification test results obtained on the CAL.

Table 1-1. Test Requirements and Results Summary

EMI Test Procedure: LAT-PS-03929-03		Test Sample: CAL Tower Module S/N: FM 101
EMITP reqs.	QUALIFICATION TESTS	TEST RESULTS
4.1	EMI Test Preliminary Set-Up (and Bonding Measurements Only)	Satisfactory (section 5.1)
4.2	Pre-EMI Functional Test of Flight CAL	Satisfactory (section 5.2)
4.3	CE102 Conducted Emissions, Power Leads 10kHz - 10MHz	Passed (section 5.3)
4.4	CECM Conducted Emissions, Time Domain 150MHz Bandwidth	Passed (section 5.4)
4.5	CS102 Conducted Susceptibility, Power Leads 10kHz - 10MHz	Passed (section 5.5)
4.6	CSCM Conducted Susceptibility, Common Mode 30Hz - 150MHz	Passed (section 5.6)
4.7	CS06 Conducted Susceptibility, Power Leads Spikes	Passed (section 5.7)
4.8	RE101 Radiated Emissions, Magnetic Field 20Hz - 50kHz	Passed (section 5.8)
4.9	RE102 Radiated Emissions, Electric Field 10kHz - 18GHz	Passed (section 5.9)
4.10	RS101 Radiated Susceptibility, Magnetic Field 20Hz - 50kHz	Passed (section 5.10)
4.11	RS103 Radiated Susceptibility, Electric Field 30MHz - 18GHz	Passed (section 5.11)
4.12	Static Magnetic Field	Verified by Analysis (section 5.12)
4.13	Post EMI/EMC Performance Test	Satisfactory (section 5.13)

**1.3 Applicable Documents.** The following documents were referenced during the preparation and development of the test requirements and procedures for the CAL.

## 1.3.1 Military

MIL-STD-461E	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
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## NCST-TR-#####

MIL-STD-462	Measurement of Electromagnetic Interference Characteristics
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## 1.3.2 NRL

LAT-PS-03929-03 SSD-TP-GL001	GLAST LAT Calorimeter Subsystem Electromagnetic Interference (EMI) Test Procedure
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## 2 UNIT UNDER TEST (UUT)

**2.1 UUT Description.** The CAL Tower Module (one of sixteen that comprise the CAL subsystem) consists of:

- CAL Module (Flight Article), P/N: LAT-DS-04539, S/N: FM101
- Tower Electronics Module (TEM-EM2 non-flight ground test unit)
- Tower Power Supply (TPS-EM2 non-flight ground test unit)

**2.2 UUT Electromagnetic Compatibility Requirements.** The CAL was tested to the applicable qualification requirements as specified in the Electromagnetic Interference (EMI) Test Procedure, LAT-PS-03929-03. The applicable tests are listed in Table 1-1.

**2.3 UUT Configuration.** The general test configuration for the CAL is specified in the Electromagnetic Interference (EMI) Test Procedure, LAT-PS-03929-03. The Support Test Equipment (STE) simulated in-flight power conditions and provided appropriate communications links and loads for the CAL.

**2.3.1 Modes of Operation.** The CAL was configured in its most active mode for emissions testing and also for susceptibility testing. The CAL operation modes (Register Exerciser Test and the Charge Injection Calibration) are defined in LAT-MD-1502.

**2.3.2 Connector and Cable Configuration.** Test cables and connectors used throughout all the EMC tests were similar in construction to the actual flight harness. The test harness was made up of shielded twisted pairs with a gross overall shield. The shields on both ends were terminated to the connector back shells.

**2.3.3 Power Requirements.** The general test setup was in accordance with Figure 3-1 and Figure 3-2 of the Electromagnetic Interference (EMI) Test Procedure, LAT-PS-03929-03. The CAL obtained all its DC power from the STE. A 10 uF Line Stabilization Capacitors (LSC) was used to connected the primary +28v Line to the Test Bench Ground Plane (TBGP) and a second LSC used to connect the primary RETURN Line to the TBGP.

## 3 EMI TEST FACILITIES

**3.1 Test Data.** The data collected during the EMI test was recorded on a variety of media, including spectrum analyzer plots and data sheets with hand entries. EMI test data are provided in Appendix A through Appendix H. A log book was also maintained and photographs taken which documented the

**NCST-TR-#####**

chronological activity of this test effort. A copy of the logbook pages are provided in Appendix I. Photographs of the test set-up and configurations are provided in Appendix J.

**3.2 Test Enclosure.** All tests were performed in the EMI shielded anechoic chamber (Bldg. A59) capable of attenuating electromagnetic signals 100 dB from 10 kHz to 18 GHz. All power cables and data lines from the Support Test Equipment (STE) to the UUT were routed through a penetration connector panel on the shielded enclosure.

**3.3 Ground Plane.** The UUT was installed (IAW Figure 3-2 of the EMI Test Procedure, LAT-PS-03929-03) on a ground plane Grid Simulator that closely approximates the actual in flight installation. The CAL Module was bonded to the Grid Simulator using the CAL mounting flanges. The DC resistance between the UUT and the ground plane was measured to be less than 2.5 milli-ohms. The ground plane Grid Simulator was also electrically bonded to the floor and walls of the shielded enclosure at least once every 1-meter.

**3.4 Test Equipment.** Only calibrated equipment, antennas, and sensors were used to obtain quantitative measurements during the EMI testing.

**4 TEST PROCEDURES.** All testing was performed in accordance with the qualification requirements of the "GLAST LAT Calorimeter Subsystem Electromagnetic Interference (EMI) Test Procedure", LAT-PS-03929-03.

**4.1 Test Procedure Issues.** Any deviations from the original document were red-lined into the "as-run" EMI Test Procedure. The Test Procedure was subsequently updated and re-released with all the changes incorporated.

**5 TEST RESULTS.** Setup of the CAL, the EMI test equipment, and Support Test Equipment (STE) began on 13 September 2005 and all testing ended on 20 September 2004. All testing was done in the EMI facilities at the Naval Research Laboratory, Washington, DC. Testing was conducted in accordance with the EMI Test Procedure, except as noted in section 4.1 of this document, and the results of the individual EMC tests are explained and commented upon in the following sections.

**5.1 EMI Test Preliminary Set-Up.** The test setup of the CAL and Calorimeter Test Structure (CTS) was in accordance with Figure 3-1 and Figure 3-2 of the EMI Test Procedure. The bonding resistance between the CAL and the ground plane shall be less than 2.5 milliohms.

The bond between the CAL Base and ground plane Grid Simulator was measured to be 0.12 milliohms. The bond between the ground plane Grid Simulator and the Test Bench Ground Plane was 0.03 milliohms.

**5.2 Pre-EMI Functional Test of Flight CAL.** The Pre-EMI Comprehensive Performance and Functional Tests (as specified in LAT-PS-1370) were performed on the CAL and EM2 TEM/TPS. All test results were satisfactory. It also provided a performance baseline and established nominal system telemetry readings for the pass/fail criteria during susceptibility testing.

**NCST-TR-#####**

**5.3 Conducted Emissions, Power Leads, 10kHz - 10MHz (CE102).** The narrowband conducted emissions shall be less than the limits specified in the EMI Test Procedure, Section 4.3 for all modes of operation over the frequency range of 10 kHz - 10 MHz.

The EMI test equipment was verified for proper operation. Calibration signals were injected on the terminals of a dummy load and measurements were taken. All measured calibration signal levels were SATISFACTORY (all within +/-3 dB of the expected values).

The emissions on the +28 Vdc line and the RETURN line were all below the CE102 limits. The data plots are provided in Appendix A.

**5.4 Conducted Emissions, Time Domain, 150MHz Bandwidth (CECM).** The time domain conducted emissions shall be less than the limits specified in the EMI Test Procedure, Section 4.4 for all modes of operation. The measurements are to be taken for both common mode and differential mode.

**5.4.1 Conducted Emissions, Common Mode (CECM).** The common mode emissions, obtained with a dual trace oscilloscope which computes  $(A+B)/2$  (where A and B are the +28 Vdc power and RETURN, respectively), shall be less than 200 millivolts peak-to-peak.

The common mode emissions were all below the CECM limits. The data plots are provided in Appendix B.

**5.4.2 Conducted Emissions, Differential Mode (CEDM).** The differential mode emissions, obtained with a dual trace oscilloscope which computes  $(A-B)$  (where A and B are the +28 Vdc power and RETURN, respectively), shall be less than 250 millivolts peak-to-peak.

The differential mode emissions were all below the CEDM limits. The data plots are provided in Appendix B.

**5.5 Conducted Susceptibility, Power Leads, 10kHz - 10MHz (CS102).** The UUT shall not be adversely degraded when subjected to a high frequency (10 kHz - 10 MHz) sinusoidal ripple current on the primary input power line. The amplitude of the ripple current is specified in the EMI Test Procedure, Figure 4-5.

The EMI test equipment was calibrated to produce the required injected amplitudes over the entire frequency range. A coupling transformer driving a 0.5 ohm load was used from 10 kHz to 150 kHz, and a coupling capacitor driving a 50 ohm load was used from 150 kHz to 10 MHz.

The CAL performed without any degradation. The data plots of the CS102 injected current are provided in Appendix C.

**NCST-TR-#####**

**5.6 Conducted Susceptibility, Common Mode, 30Hz - 150MHz (CSCM).** The UUT shall not be adversely degraded when subjected to a high frequency (30 Hz - 150 MHz) sinusoidal ripple voltage on the primary input power line. The amplitude of the ripple is 400 milliVolts peak-to-peak across the entire frequency range. The requirement is also met when the EMI power source is adjusted to dissipate the following power levels and the UUT is not susceptible: 80 watts in a 0.5 ohm load over the frequency range 30 Hz to 150 kHz, and 1 watt in a 50 ohm load over the frequency range 150 kHz to 150 MHz.

The EMI test equipment was calibrated to dissipate the required power over the entire frequency range. A coupling transformer driving a 0.5 ohm load was used from 10 kHz to 150 kHz, and a coupling capacitor driving a 50 ohm load was used from 150 kHz to 150 MHz.

The CAL baseline noise floor was 15-20 units before any CSCM voltage injection. The noise floor increased by up to 40 units when the 400 mV pk-pk was injected on either the +28Vdc line or the RETURN line. It occurred in the frequency range from 150 kHz to 1 MHz. The noise floor returned to normal at all frequencies above 1 MHz. A susceptibility threshold was determined, and the noise floor was not affected at a levels at or below 141 millivolts (pk-pk).

It was originally reported as a CSCM failure. After further analysis by the CAL engineers, it was determined that the 40 unit increased in noise floor was still within specification for their receiver and therefore not considered a failure. Thus the unit passed CSCM. Note: there were no register read errors at any frequency or CSCM injection level.

Otherwise, the CAL performed without any degradation and passed the CSCM requirement. The data plots of the CS102 injected current are provided in Appendix C.

**5.7 Conducted Susceptibility, Power Leads, Spikes (CS06).** The UUT shall not be adversely degraded by the presence of transient spikes on the primary input power line. The peak transient voltage, relative to the nominal line voltage shall be 20 volts line-to-line, both positive and negative polarities, at a repetition rate of 10 pulses per second.

The CAL performed without any degradation in the presence of the spike both positive and negative spike polarities. The data plots of the CS02 injected voltage (and calibrated power level) are provided in Appendix D.

**5.8 Radiated Emissions, Magnetic Field, 20Hz - 50kHz (RE101).** The radiated magnetic field emissions shall be less than the limits specified in the EMI Test Procedure, Section 4.8 for all modes of operation over the frequency range of 20 Hz - 50 kHz.

The EMI test equipment was verified for proper operation. Calibration signals were injected on the loop sensor cable and measurements were taken. All measured calibration signal levels were SATISFACTORY (all within +/-3 dB of the expected values). The measured resistance of the loop sensor was SATISFACTORY.

The magnetic field emissions measure at a distance of 1 meter from the CAL were all below the RE101 limit. The data plots are provided in Appendix E.

**NCST-TR-#####**

**5.9 Radiated Emissions, Electric Field, 10kHz - 18GHz (RE102).** The radiated electric field emissions shall be less than the limits specified in the EMI Test Procedure, Section 4.9 for all modes of operation. Two notches were also specified: 14 dBuV/m at 1575  $\pm$  25 MHz (GPS), and 25 dBuV/m at 2035  $\pm$  265 MHz (S-Band).

The EMI test equipment was verified for proper operation. Calibration signals were injected on the terminals of the antenna cable and measurements were taken. All measured calibration signal levels were SATISFACTORY (all within  $\pm$  3 dB of the expected values).

Ambient measurements were taken with the CAL power off, and with all the EMI test equipment and Support Test Equipment (STE) turned on. All measured ambients over the entire frequency range were SATISFACTORY (at least 6 dB below the RE102 limits).

The electric field emissions from 10 kHz - 18 GHz, measure at a distance of 1 meter from the CAL were all below the RE102 limit. The CAL originally had harmonics of 20 MHz in the GPS and the S-Band notches. Troubleshooting revealed that the source of the emissions was the TEM/TPS, not the CAL. It also revealed that the TEM/TPS Box Shield (see EMI Test Procedure, Figure 2-2) was not reinstalled after the Conducted Emissions and Conducted Susceptibility testing was concluded (Note: the box shield needed to be removed during the Conducted tests to provide access to the cable connectors and harness). After the TEM/TPS Box Shield was installed, all emissions in the GPS and the S-band notches were below the applicable limit. The data plots are provided in Appendix F.

**5.10 Radiated Susceptibility, Magnetic Field, 20Hz - 50kHz (RS101).** The UUT shall not be adversely degraded when subjected to the low frequency (20Hz - 50kHz) radiated magnetic field levels specified in the EMI Test Procedure, Section 4.10 for all modes of operation.

The EMI test equipment was calibrated to produce the required magnetic field levels from the radiating loop over the entire frequency range. The radiating loop/test equipment was then set to produce the required level at 1 kHz and the level was measured with a field monitoring loop/receiver to verify proper operation. The measured signal level was SATISFACTORY (within  $\pm$  3 dB of the expected value).

The CAL performed without any degradation at all radiating loop test positions. The radiating loop was repositioned over each 10cm by 10cm area on each face of the CAL. The data plots of the RS101 radiated magnetic field levels are provided in Appendix G.

**5.11 Radiated Susceptibility, Electric Field, 30MHz - 18GHz (RS103).** The UUT shall not be adversely degraded when subjected to the high frequency (30 MHz - 18 GHz) radiated electric field levels specified in the EMI Test Procedure, Section 4.10. The radiated fields shall be pulse modulated at 1 kHz with 50% duty factor over the entire frequency range.

The CAL performed without any degradation. The data plots of the RS103 radiated electric field levels are provided in Appendix H.

**NCST-TR-#####**

**5.12 Static Magnetic Field.** The UUT shall not be adversely degraded when subjected to a static magnetic field of 2 Gauss.

The CAL performance in a static magnetic field was verified by analysis. Therefore, testing was not required.

**5.13 Post EMI/EMC Performance Test.** The post-EMI Comprehensive Performance and Functional Tests (as specified in LAT-PS-1370) were performed on the CAL and EM2 TEM/TPS. All test results were satisfactory.

NCST-TR-#####

## Appendix A - CE102 Test Data

(Plot\_001 to Plot\_003)

NCST-TR-#####

## Appendix B - CECM Test Data

(Plot\_004 to Plot\_018)

NCST-TR-#####

## Appendix C - CS102 & CSCM Test Data

(Plot\_022 to Plot\_051)

NCST-TR-#####

## Appendix D - CS06 Test Data

(Plot\_019 to Plot\_021)

NCST-TR-#####

## Appendix E - RE101 Test Data

(Plot\_084 to Plot\_096)

NCST-TR-#####

## Appendix F - RE102 Test Data

(Plot\_052 to Plot\_083, and  
Plot\_097 to Plot\_104)

NCST-TR-#####

## Appendix G - RS101 Test Data

(Plot\_117 to Plot\_163)

NCST-TR-#####

## Appendix H - RS103 Test Data

(Plot\_105 to Plot\_116)

NCST-TR-#####

## Appendix I - Log Book Entries

**NCST-TR-#####**

## **Appendix J - Photographs**